From: Powers, David
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Cc: Leinenbach, Peter; Kubo, Teresa; Henning, Alan
Subject: FW: Email 2 of 5
Date: Thursday, February 06, 2014 11:58:30 AM
Attachments: Idaho Shade Requirements for Forested Lands.pdf
ID SPZ scenario options Memo - Enclosure.pdf

Josh – the last e-mail on this topic. The *"ID SPZ scenario scenario options memo"* includes EPA's independent analysis of the field data used by IDL to develop shade rule options with appropriate modeling corrections and several different relative stocking (RS) options. The memo includes important, relevant information to the OR FPA rulemaking…and is consistent with Ripstream results. Pete is your best contact for questions on the modeling. EPA's comment letter is also attached.

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Shade modeling of riparian management scenarios proposed for CGIF stands - March 13, 2013

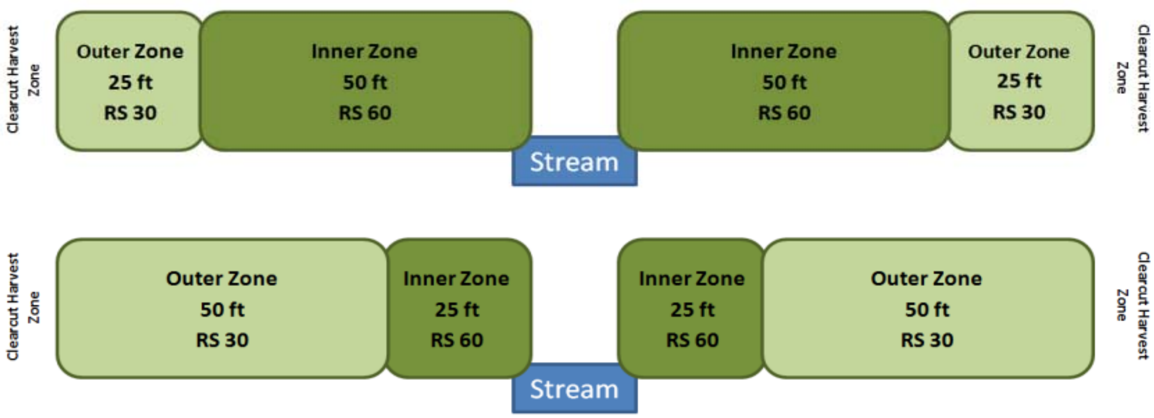
Summary

The shade modeling effort presented in this memorandum evaluated the potential shade loss associated with proposed riparian management scenarios reported to the Idaho Forest Protection Act (IFPA) shade rule subcommittee[1]. Specifically, riparian management scenarios proposed to the subcommittee consisted of a combination of three different forest management components:

1) clearcut removal of all trees located outside of the inner and outer riparian buffer zone;
2) variable riparian thinning levels within a variable **inner** riparian buffer zone width[2]; and
3) variable riparian thinning levels within a variable **outer** riparian buffer zone width[3] (**Figure 1**).

It is important to note that harvest actions within each zone will influence the potential shade production associated within the other buffer zones. This interaction will be described in this memorandum.

Figure 1. Examples of possible harvest buffer configurations.



Results of this analysis for CIGF forests stands are presented in **Table 1** and values in this table are expressed as the average shade loss associated with harvest along 10ft, 20ft, and 30ft wide stream channels.

It is important to point out that there was a good correspondence in predicted shade loss between the two modeling efforts (**Table 2**). However, the predicted shade loss associated with this effort is slightly higher for most of the compared scenarios. This result is expected because this new modeling effort incorporated several solutions outlined in the USEPA letter to the IFPA shade rule sub-committee in April 2012, as presented in the following pages.

[1] Memorandum titled "Using Stream Shade and Large Wood Recruitment Simulation Models to Inform Forest Practices Regulations in Idaho", by Mark Teply, Cramer Fish Sciences, January 2012.
[2] Inner riparian zone refers to the riparian zone located between the stream and the outer riparian zone.
[3] Outer riparian zone refers to the riparian zone located between the inner riparian zone and the clearcut zone.

Table 1. Modeled shade loss associated with various riparian buffer configurations for CIGF stands

Scenario (Two Bank Treatments)[4]	Average Shade Loss (Range) [5]	Scenario (Two Bank Treatments)	Average Shade Loss (Range)
A-1 Inner and Outer Zones 75 ft RS 100 Stream	**6** (4 to 8)	C-1 Outer Zone 50 ft RS 60 | Inner Zone 25 ft RS 100 Stream	**7** (5 to 9)
A-2 Inner and Outer Zones 75 ft RS 60 Stream	**9** (7 to 11)	C-2 Outer Zone 50 ft RS 30 | Inner Zone 25 ft RS 100 Stream	**11** (8 to 14)
A-3 Inner and Outer Zones 75 ft RS 30 Stream	**17** (13 to 22)	C-3 Outer Zone 50 ft RS 30 | Inner Zone 25 ft RS 60 Stream	**12** (9 to 16)
B-1 Inner and Outer Zones 50 ft RS 100 Stream	**14** (10 to 17)	C-4 Outer Zone 50 ft RS 10 | Inner Zone 25 ft RS 60 Stream	**18** (14 to 24)
B-2 Outer Zone 25 ft RS 60 | Inner Zone 25 ft RS 100 Stream	**14** (11 to 19)	D-1 Outer Zone 25 ft RS 60 | Inner Zone 50 ft RS 100 Stream	**6** (4 to 8)
B-3 Outer Zone 25 ft RS 30 | Inner Zone 25 ft RS 100 Stream	**16** (12 to 22)	D-2 Outer Zone 25 ft RS 30 | Inner Zone 50 ft RS 100 Stream	**8** (6 to 10)
B-4 Outer Zone 25 ft RS 30 | Inner Zone 25 ft RS 60 Stream	**18** (14 to 24)	D-3 Outer Zone 25 ft RS 30 | Inner Zone 50 ft RS 60 Stream	**10** (8 to 13)
B-5 Outer Zone 25 ft RS 10 | Inner Zone 25 ft RS 60 Stream	**22** (16 to 28)	D-4 Outer Zone 25 ft RS 10 | Inner Zone 50 ft RS 60 Stream	**12** (9 to 16)

[4] Two bank treatments with clearcut harvest located outside of the outer buffer zone.

[5] Average of 10ft, 20ft, and 30ft stream channels, averaged for the four CIGF forest groups listed in Table 3. "Range" is the minimum and maximum shade loss associated with the 10ft, 20ft, and 30ft stream channels for the four forest groups listed in Table 3.

Table 2. Comparison of predicted shade loss associated with riparian management for CIGF stands presented in the CFS modeling effort and this current effort.

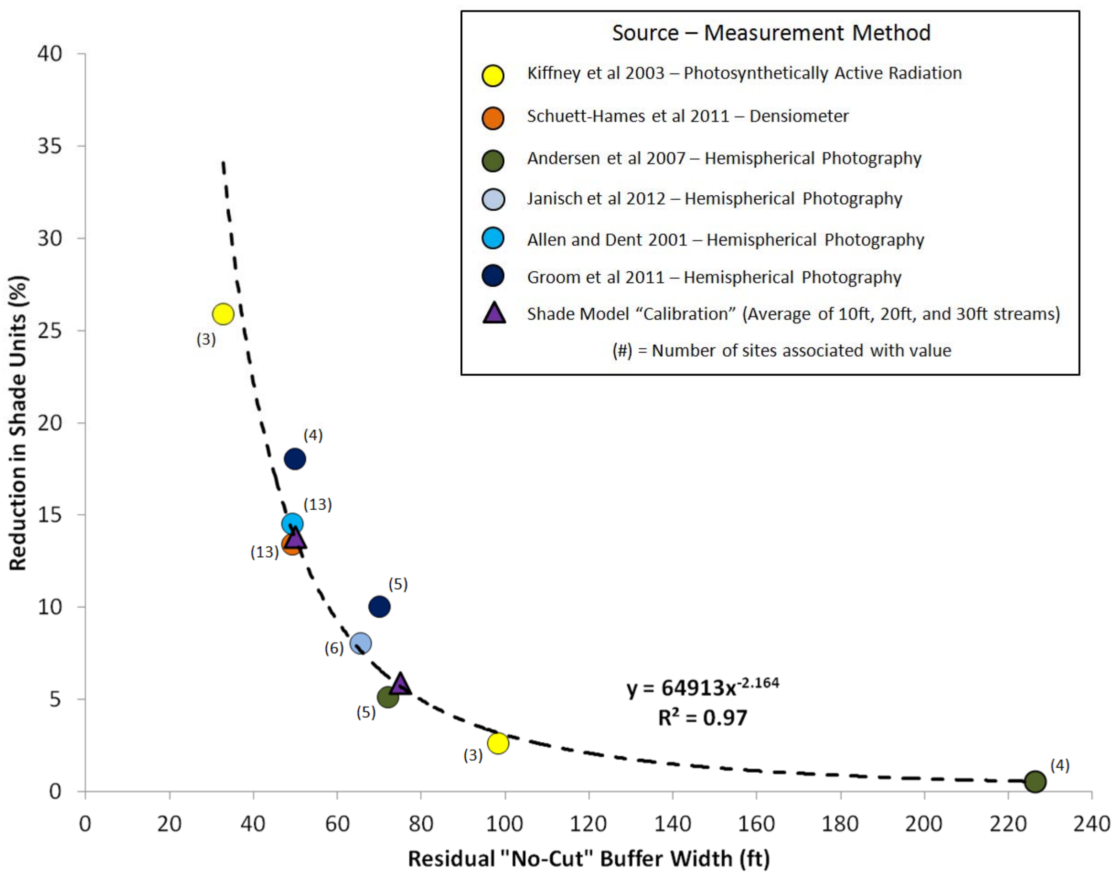
Scenario (Two Bank Treatments)	Results reported in Current Modeling Effort Average Shade Loss (Range)	Results reported in CFS Modeling Effort[6] Average Shade Loss
A-2: Inner and Outer Zones 75 ft RS 60; Stream	**9** (7 to 11)	**10**
A-3: Inner and Outer Zones 75 ft RS 30; Stream	**17** (13 to 22)	**30**
B-1: Inner and Outer Zones 50 ft RS 100; Stream	**14** (10 to 17)	**12**
B-2: Outer Zone 25 ft RS 60; Inner Zone 25 ft RS 100; Stream	**14** (11 to 19)	**13**
B-3: Outer Zone 25 ft RS 30; Inner Zone 25 ft RS 100; Stream	**16** (12 to 22)	**16**
C-1: Outer Zone 50 ft RS 60; Inner Zone 25 ft RS 100; Stream	**7** (5 to 9)	**5**
C-2: Outer Zone 50 ft RS 30; Inner Zone 25 ft RS 100; Stream	**11** (8 to 14)	**8**
C-3: Outer Zone 50 ft RS 30; Inner Zone 25 ft RS 60; Stream	**12** (9 to 16)	**10**

[6] Values obtained from Teply and Ceder (2012) and "Shade Rule Handout-FRAAC Mtg-2-4-13.pdf"

Methods

The "shade.xls" modeling tool, developed by the Washington Department of Ecology[7], was used to develop estimates of shade loss associated with riparian harvest along CIGF forest stands. Specifically, the Chen et al (1998) shade algorithms in the "shade.xls" shade modeling tool were used to estimate shade conditions. An attempt was made to use similar modeling parameters used during the "January 2012 CFS Report" modeling effort[8]. Other modeling details include: 1) utilized the "delta Chen" modeling procedure (as described in the 4/2012 USEPA letter to the IFPA shade subcommittee), 2) utilized the "Riparian Extinction" coefficient; 3) utilized the Bras solar radiation model; and 4) calibrated (i.e., parameter estimation) the shadow density factor for the additivity of overlapping buffers ("shddenadd") to 0.4. That is, this "shddenadd" value produced the best fit between modeled and measured shade loss associated with a narrowing of the buffer width (**Figure 2**), as described further in **Appendix A**.

Figure 2. Observed shade loss in field studies and modeled shade loss[9]
[Model results are purple triangles represent results associated with scenarios A-1 and B-1 in Table 1]



[7] This modeling tool can be downloaded from - http://www.ecy.wa.gov/programs/eap/models.html.
[8] i.e., 8/1 modeling date, modeling location was central Idaho, and used Central Idaho Grand Fir summary stand data which was obtained from Mark Teply at Cramer Fish Sciences.
[9] "Residual "No-Cut" Buffer Width" refers to the un-cut riparian forest zone located between the stream and the outer clearcut harvest zone. An annotated bibliography for studies listed in this figure is presented in **Appendix B**.

Modeling Assumptions

It was assumed in the modeling effort that all of the trees were removed within the designated "clearcut" harvest zone. Also, it was assumed that thinning activities uniformly removed trees among the different size classes within the stand (i.e., thinning activities did not affect the average height of the stand). Finally, it was assumed that thinning activities did have an effect on the stand canopy cover (canopy closure) conditions. This last factor was explicitly estimated during modeling efforts.

Initial Riparian Stand Conditions Used in the Model (i.e., Pre-Harvest Conditions)

The theoretical maxima derived from IDL CFI[10] plots for the Central Idaho Grand Fir (CIGF) was used as the basis for the initial riparian pre-harvest conditions. Of particular note was that the theoretical maximum Relative Density (RDsum) for CIGF stands was designated as 70.6. Each of the four reported CIGF forest types were evaluated during this analysis (**Table 3**).

Table 3. Central Idaho Grand Fir (CIGF) Vegetation Characteristics

CIGF Category Name	Average Height (m)	Average Canopy Cover (%)
Group 1 - Stands with Relative Stocking > 55 & Avg Ht > 22.5m	28.2 (93 ft)	57
Group 2 - Stands with Relative Stocking > 55 & Avg Ht < 22.5m	18.5 (61ft)	72
Group 3 - Stands with Relative Stocking > 55 & Avg Ht > 22.5 & Max CC	26.7 (88ft)	74
Group 4 - Stands with Relative Stocking > 55 & Max Avg Ht	35.8 (118 ft)	64

Evaluation of Proposed Buffer Width Reduction on Stream Shade Conditions

This section of the document presents the methods used to evaluate the effects of tree removal ("clearcut") in the outer section of the riparian buffer (see **Figure 1**). This effect was addressed in the model in two ways.

The first method (and most the direct) was addressed through directly reducing the width of the riparian **buffer width** in the model. For example, if the residual buffer[11] width was 75ft, then the model input parameter for the buffer width was set at 75 feet.

The second method was developed through evaluating the effects of the harvest management on the **canopy cover** associated with the residual buffer. A detailed description of the methods used to estimate this parameter is presented in the following 6 pages[12].

[10] Idaho Department of Lands Continuous Forest Inventory plots
[11] Residual buffer is defined as the riparian buffer which is located between the stream and the clearcut harvest
[12] This method was also described in detail in the 4/2012 USEPA letter to the IFPA shade sub-committee.

Background Information for the Evaluation of Proposed Buffer Width Reduction

The canopy density of the stand determines the rate at which the direct beam solar radiation is blocked, with greater levels of blockage occurring with higher canopy densities. Accordingly, the canopy density of the riparian vegetation stand directly affects stream shade. Canopy density is accounted for in the Chen shade model through an extinction coefficient (λ):

$$\lambda = \frac{\ln{(1 - canopy\ density)}}{Vegetation\ Height}$$

(Equation 16a in Chen et al 1998)

The extinction coefficient (λ) is then used to estimate the effective shade density (SHDDEN):

$$SHDDEN = 1 - \exp{(-\lambda * The\ pathlength\ of\ the\ sunlight\ through\ the\ riparian\ stand)}$$

(Equation 16f in Chen et al 1998)

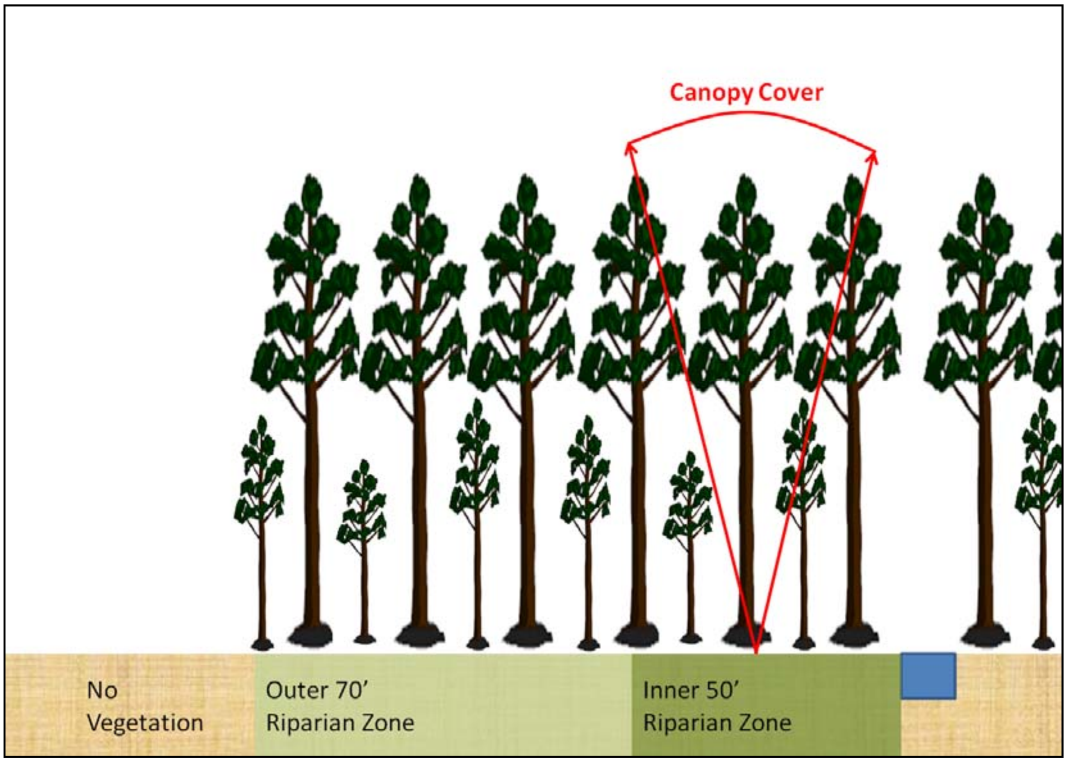
It is important to point out that the canopy density parameter in the equation above **is not** associated with the vertical projection of the canopy onto a horizontal surface[13] (**Figure 3**). Rather, it is an estimate of the canopy measured at the angle above the horizon at which direct-beam solar radiation passes through the riparian canopy (**Figure 4**).

Accordingly, the stream shade response resulting from a narrow riparian buffer will be underestimated if the "canopy cover" definition of canopy density is used as an input parameter for calculating the extinction coefficient (λ) in the Chen model. For example, the bottom image associated with **Figure 3** illustrates that it is possible for the vertical projection of "canopy cover" to not change with a narrowing of the riparian buffer width. Alternatively, the bottom image associated with **Figure 4** shows that the canopy density is directly influence by the width of the riparian buffer when measured from an angle above the horizon. In other words, as the buffer width decreases, horizontal canopy density also decreases, ultimately resulting in lower stream shade conditions. In summary, narrowing the riparian buffer decreases the density of the riparian canopy through which solar radiation passes (i.e., canopy density), which subsequently reduces stream shade conditions.

Accordingly, the canopy density input parameter used to calculate the riparian extinction coefficient (λ) must account for this effect for the model to accurately simulate stream shade response associated with a narrowing of the riparian buffer.

[13] This vertical measure of canopy density is often referred to as "canopy cover" and is measured with devices such as a spherical densitometer.

Figure 3. Illustration of the relationship between vertical canopy density (canopy cover) and buffer width



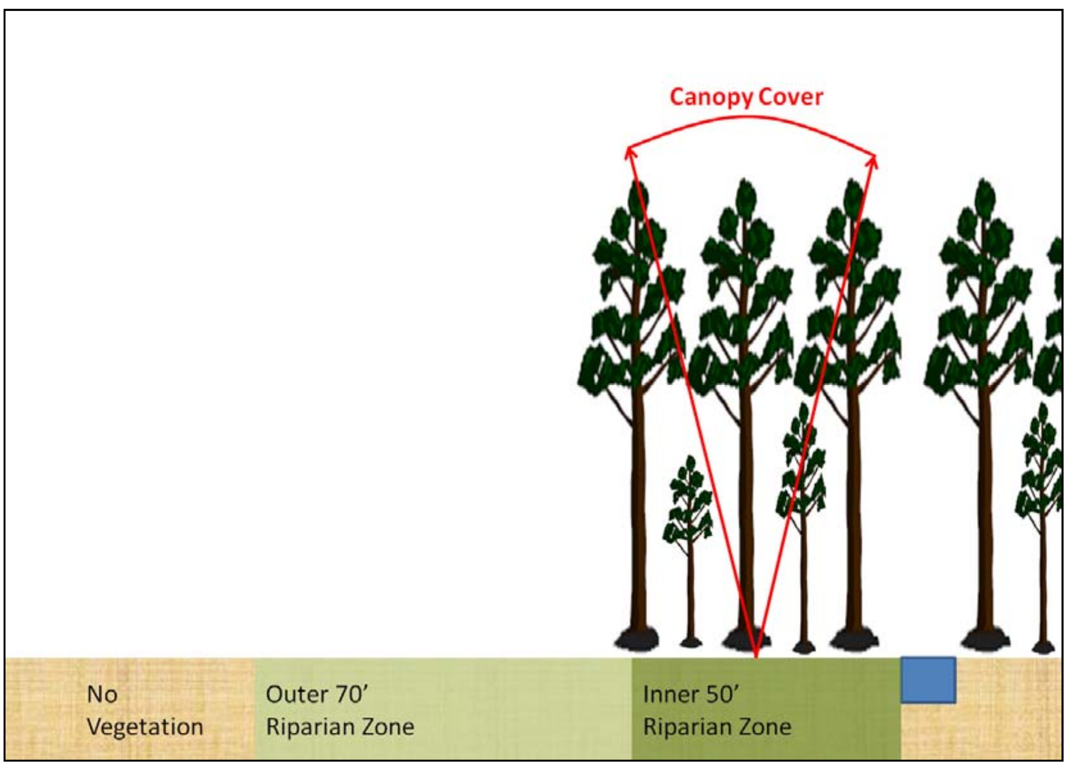
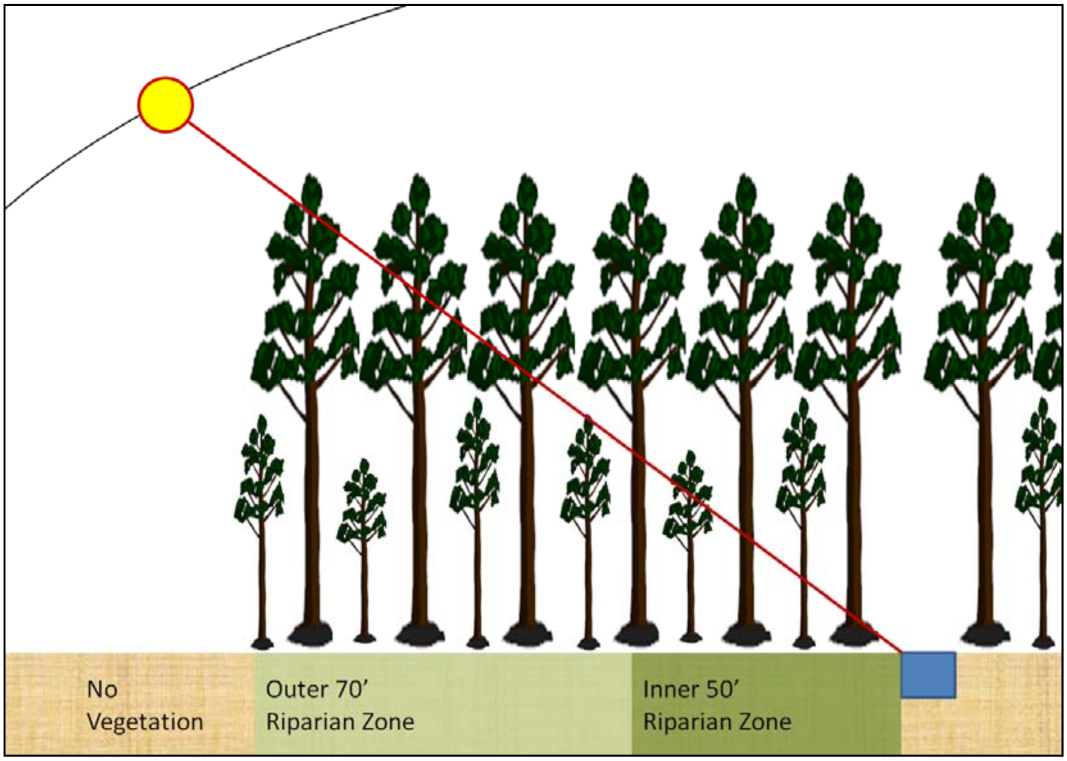
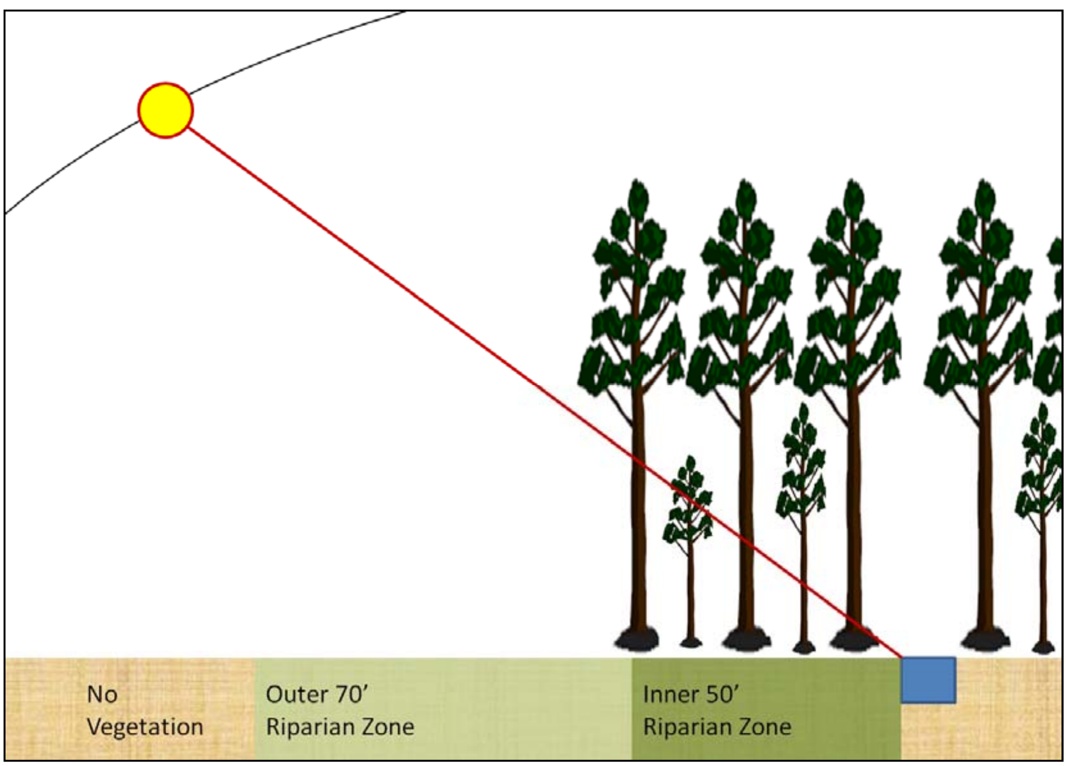


Figure 4. Illustration of the relationship between horizontal canopy density and buffer width





Estimating the effect of a narrowing of the riparian buffer width on canopy cover conditions

Beschta et al (1987) reported that the effectiveness of a buffer strip in providing stream shade can be determined by measuring the angular canopy density (ACD). ACD evaluates the horizontal plane of canopy density for the portions of the riparian stand which provide shade during the mid part of the day (usually between 10 am and 2 pm) (**Figure 5**). **Figure 6** illustrates the relationship between ACD and the riparian buffer width (Brazier and Brown, 1973). While it is theoretically possible for natural forest vegetation to have ACDs of 100%, indicating complete shading from incoming solar radiation, the ACD of mature undisturbed stands generally falls between 75 and 90% (Brazier and Brown 1973, Steinblums et al., 1984, Erman et al., 1977). In addition, ACD increases become negligible at some buffer strip width as a result of the "tree behind a tree" phenomenon, and/or the vegetation in distant portions of the riparian stand not being tall enough to cast a shadow over the stream surface.

The trend line presented in **Figure 6** can be used as a tool to evaluate the influence that riparian buffer width reductions have on the riparian canopy density (**Table 4**). Specifically, the estimated reduction in canopy density presented in this table can be used as a weighting factor to evaluate the effects of narrowing of the riparian buffer width on the canopy cover conditions of the residual buffer (**Table 5**). For example, narrowing of the riparian buffer to 75ft will result in a 5% loss of the "effective" canopy cover associated with the residual buffer: Using the example in **Table 5**, a 5% reduction in canopy density would result in a 4 unit loss of canopy density within the remaining riparian buffer (i.e., 74% - (0.95*74%) = 70%).

Table 4. Calculated Effect of Buffer Width on Angular Canopy Density

Buffer Strip Width (feet)	Estimated ACD	Percent Reduction from 100' buffer
100 (or 30.5 meters)	77	0%
75 (or 22.9 meters)	73	5%
50 (or 15.2 meters)	67	13%
25 (or 7.6 meters)	57	25%

Table 5. Example of Canopy Density Change for Narrowing Buffer Width Conditions

Buffer Strip Width (feet)	Percent Reduction from 100' buffer	Observed Canopy Cover at a 100' Buffer	Estimated Canopy Density at new buffer width conditions
100 (or 30.5 meters)	0%	74%	74%
75 (or 22.9 meters)	5%	74%	70%
50 (or 15.2 meters)	13%	74%	65%
25 (or 7.6 meters)	25%	74%	55%

Figure 5. Illustration of the relationship between angular canopy density (ACD) and buffer width

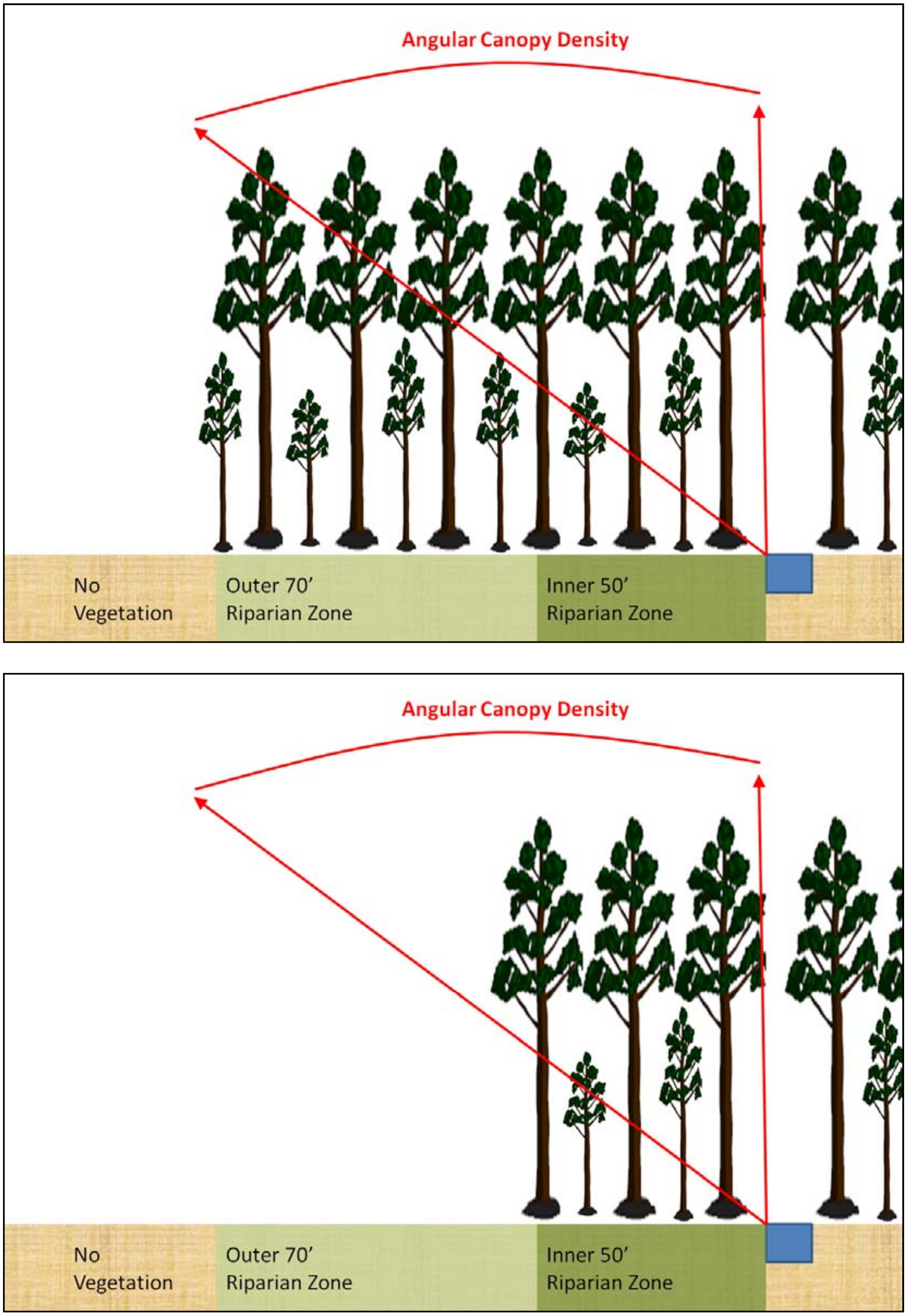
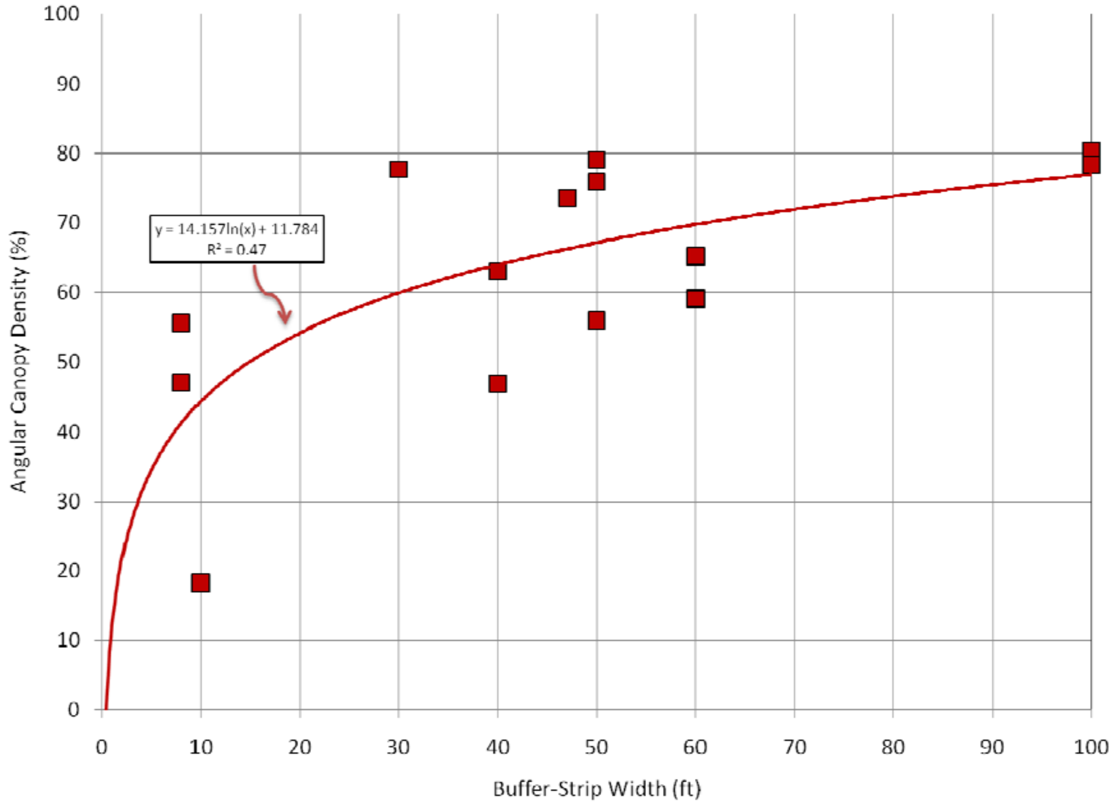


Figure 6. The relationship between measured Angular Canopy Density (ACD) and buffer strip width (Data from Table 1 in Brazier and Brown 1973).



Evaluation of Proposed Thinning Harvest Activities

The next step evaluates the effect of thinning harvest activities on stream shade conditions.

During past modeling efforts[14], thinning activities within riparian stands are described in terms of Relative Stocking (RS). Available shade models do not directly utilize RS as an input parameter, and therefore this variable needs to be translated into an appropriate model input variable: The three steps outlined below present the methods used to accomplish this task.

Step One – Define RS in terms of RDsum

RS is defined as the percent difference of the observed RDsum at a site from the theoretical maximum RDsum for that stand. Recall that in the case for CIGF, the theoretical maximum RDsum was 70.6, which corresponds with a RS of 100 (i.e., (70.6/70.6)*100 = 100). Accordingly, a RS of 60 for a CIGF stand would be associated with a RDsum of 42 (i.e., 70.6 * 0.6 = 42). Similarly, a RS of 30 and 10 would be associated with a RDsum of 21 and 7, respectively (**Table 6**).

[14] 1/2012 and 11/2012 CFS reports to the IFPA shade sub-committee

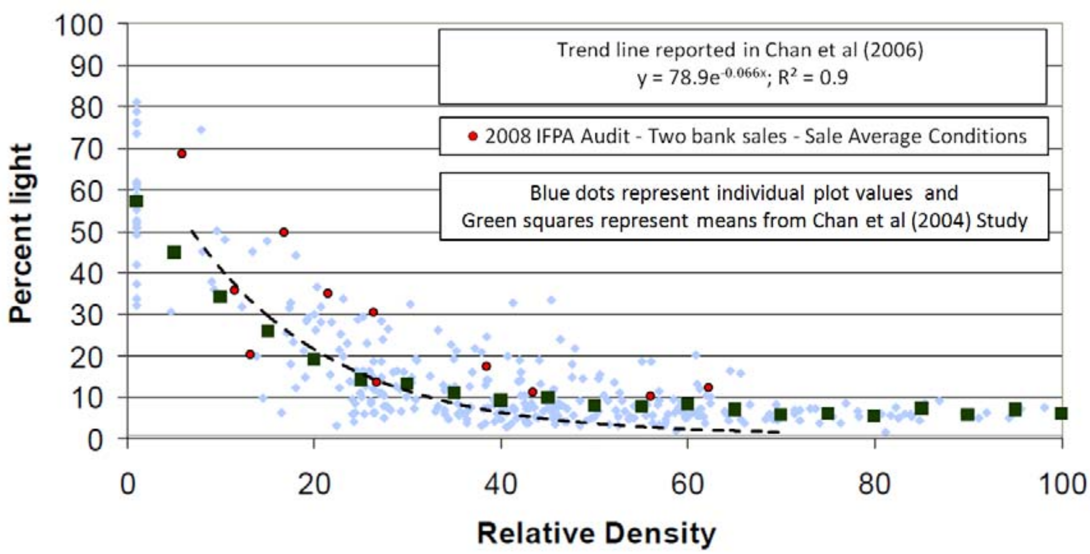
Table 6. Association between RS and RDsum for CIGF stands	
Relative Stocking	Corresponding Relative Density
100	70.6
60	42
30	21
10	7

Step Two – Associate RDsum in terms of stand openness

Field studies have shown that the "openness" of a forest stand generally increases as the stand becomes less dense (**Figure 7**) [15]. In other words, more light penetrates through the stand at lower stocking levels (i.e., RDsum levels). However, this relationship is not linear; little change in skylight occurs with changes in RD within the upper range (i.e., > 50), and large changes of "openness" occurs with changes in RD within the lower range (i.e., < 25)

Proposed thinning activities will reduce the vegetation density within the stand. Therefore, based on the relationship presented in **Figure 7**, thinning activities are anticipated to increase the amount of light transmitted through the thinned stand. For example, the dashed trend line presented in **Figure 7** indicates that stand openness will increase by 4.3% when the RDsum is 42, as compared to RDsum maximum (i.e., 70.6). In other words, thinning a CIGF stand to an RS of 60 will result in a 4.3% loss of canopy cover. Stand "openness" associated with various RS conditions are presented in **Table 7**.

Figure 7. The association between relative density and percent skylight in forest stands.



[15] "Openness" is defined as the amount of light transmitted through the forest stand. "Openness" is the inverse of canopy closure.

Table 7. Association between RDsum and increases "openness" of for CIGF stands	
Relative Density	Corresponding Increase in stand "openness"
70.6	0.0%
42	4.3%
21	19.3%
7	49.4%

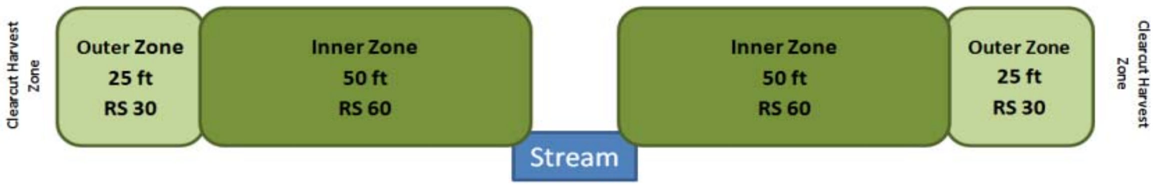
Step Three – Estimate the canopy cover associated with a RS level

The canopy cover condition associated with a particular RS level can be estimated using the information presented in the previous two steps. For example, it was estimated that a RS of 60 for the CIGF stand was associated with a RDsum of 42 (Step One – **Table 6**). It was subsequently shown that a RDsum of 42 corresponds with a 4.3% loss of canopy cover (Step Two – **Table 7**). Thus, if the initial pre-harvest canopy cover condition was 72% (i.e., Group 2 in **Table 3**), the canopy cover condition following a targeted RS 60 stand thinning would be 68.9% (i.e., 72 – (72*0.043) = 68.9).

Evaluation of Scenarios Which Both Buffer Width Reduction and Thinning Harvest Activities Occurred

Many of the proposed harvest activities include both 1) a narrowing of the riparian buffer (i.e., clearcut harvest outside of the inner and the outer riparian buffer), and 2) thinning within the inner and outer riparian buffer zones (**Figure 7**)[16].

Figure 7. An example illustration of a potential riparian harvest scenario with multiple factors



There are several interrelated effects on the potential stream shade production associated with a riparian stand exposed to such a riparian management regime. The steps listed below describe the methods used to evaluate these effects during the shade modeling effort:

- The model input parameter for the buffer width is set at 75ft (i.e., clearcut outside of this zone).

- The model input parameter for the canopy cover condition within the **outer buffer zone** reflects the influence of two factors.

    1) The <u>first factor</u> is the effects associated with a narrowing of a riparian buffer to 75ft (5% loss of canopy cover - **Table 4**). Thus, if the pre-harvest canopy cover condition was 72% (Group 2 - **Table 3**), then the “effective” canopy cover would be 68.4 (i.e., 72 – (72 * 0.05) = 68.4).

    2) The <u>second factor</u> is associated with thinning within this outer buffer zone: Targeted thinning to a RS of 30 (i.e., 19.3% loss of canopy cover - **Table 7**). Thus, if the “effective” canopy cover condition was 68.4 then the resulting model canopy cover input parameter for the outer buffer zone following both thinning harvest and buffer narrowing would be 55.2 (i.e., 68.4 – (68.4*(0.193)) = 55.2).

- The model input parameter for the canopy cover condition within the **inner buffer zone** reflects the influence of three factors.

    1) Similar to calculations associated with the outer buffer zone, the <u>first factor</u> is associated with a narrowing of the riparian buffer to 75 ft (i.e., 5% loss of canopy cover - **Table 4**). Thus, if the pre-harvest canopy cover condition was 72% (Group 2 - **Table 3**), then the “effective” canopy cover would be 68.4 (i.e., 72 – (72 * 0.05) = 68.4).

    2) The <u>second factor</u> accounts for the affect which thinning activities occurring in the outer buffer zone have on canopy cover conditions within the inner buffer zone. That is, thinning in the outer buffer zone will reduce the “effective” buffer width of the outer buffer zone through

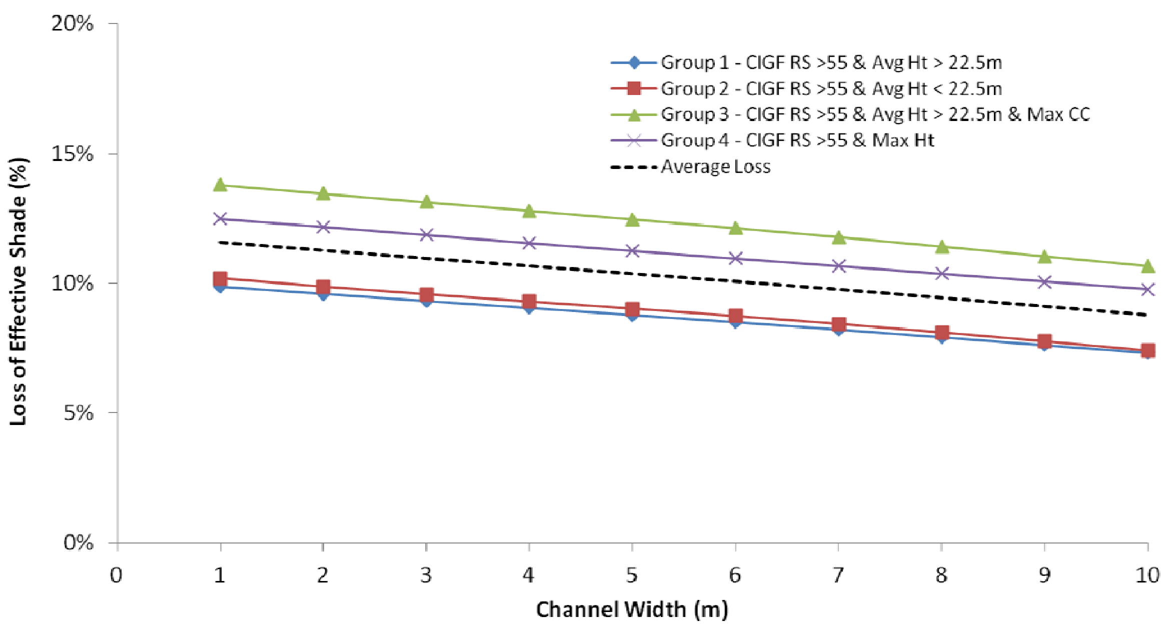
[16] The riparian harvest scenario depicted in this image is similar to Scenario D-3 in **Table 1**.

tree removal in the outer buffer zone. Specifically, the light transmissivity for the outer buffer zone will increase by 19.3% when the RS is reduced to 30 (**Table 7**). It is proposed that the canopy cover loss associated with this factor is linearly proportional to the canopy cover loss within the outer zone (i.e., 19.3% * 8% = 1.5%)[17]. Thus, if the "effective" canopy cover condition was 68.4, then including the influence of the second factor would result in a new "effective" canopy cover condition of 67.3 (i.e., 68.4 – (68.4*(0.015)) = 67.3).

3) The <u>third factor</u> is associated with thinning within this inner buffer zone: Targeted thinning to a RS of 60 (i.e., 4.3% loss of canopy cover - **Table 7**). Thus, if the "effective" canopy cover condition was 67.3, then the resulting model canopy cover input parameter for the inner buffer zone following 1) thinning harvest in the inner zone, 2) thinning harvest in the outer zone, and 3) buffer narrowing would be 64.4 (i.e., 67.3 – (67.3*(0.043)) = 64.4).

Modeled shade loss for the scenario described above is presented in **Figure 8**. The average condition for the four stands is indicated in this figure by the dashed line, while solid lines represent the modeled shade loss associated with the four CIGF stand forest types (see **Table 3**). It is important to note that there is a range of shade loss associated with these stands, with some CIGF stand groups responding at greater levels than other CIGF groups.

Figure 8. Modeled shade loss associated with the example presented above
[This scenario is similar to Scenario D-3 in **Table 1**]



[17] The estimated canopy cover loss associated with a 50 ft residual buffer is 13% (**Table 4**). This corresponds with an expected loss of 8% of canopy cover conditions within the residual buffer width between 75ft and 50ft (i.e., 13% (expected at 50ft) - 5% (expected at 75ft) = 8%).

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Teply, M., and K. Ceder (November, 2012) Memorandum - “Validation of Shade prediction Models Used to Evaluate Forest Practices Regulations in Idaho and the Idaho Forestry Program”, Cramer Fish Sciences, pp. 32

Appendix A – Parameter estimation of the shddenadd factor in the shade model

Multiple harvest activities occurred within the riparian buffer for most of the harvest scenarios listed in **Table 1**. Accordingly, it was necessary to utilize one modeling node for each of the harvest activities associated with each multi-activity scenario. The effects of each of these modeling nodes produced the final "shade" conditions associated with these multi-activity scenarios.

The "shddenadd" factor in the Chen shade model determines the additivity of shadow density for the buffer nodes used during model efforts. This factor accounts for the "tree behind the tree" component in overlapping section of the stand[18].

The "shddenadd" factor ranges from 0 to 1, with 1 representing 100% additivity of shade density between the different buffer nodes. For example, at a "shddenadd" value of 1, the final shade condition will be determined equally between each of the nodes. Alternatively, a "shddenadd" value of 0.4 would indicate that 1) the buffer segment which contributes the maximum shade density will have 100% of its effect included in final shade estimates, 2) while the remaining buffer segments will only have 40% of their shade density included in the final shade estimates.

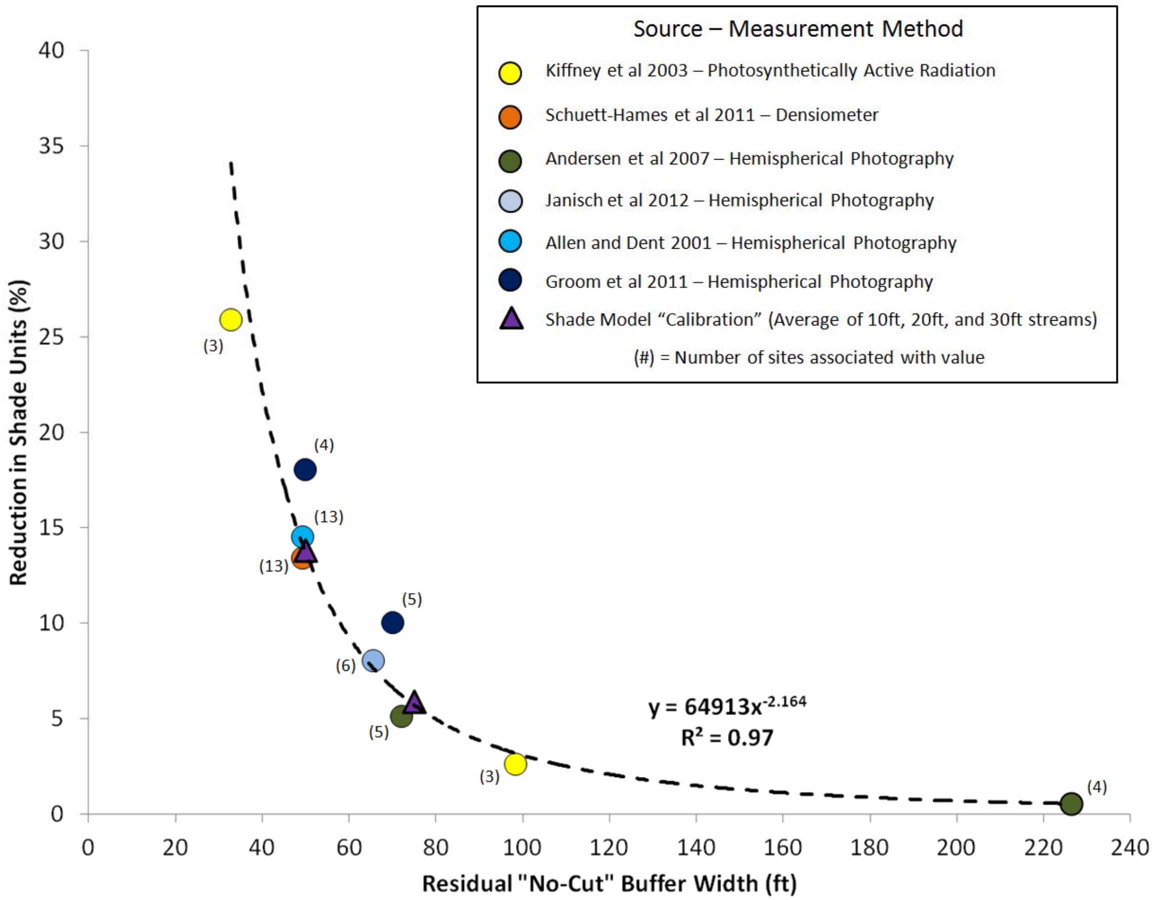
The "shddenadd" factor in the model was calibrated ("Parameter Estimation") to two (2) harvest scenarios listed in **Table 1** (i.e., Scenarios A-1 and B-1). These harvest scenarios resulted in a 50 and 75ft residual buffer width following harvest, which can be directly compared to field data results. Results of this analysis indicated that a "shddenadd" factor of 0.4 resulted in the closest association between measured and modeled shade loss conditions for these two scenarios (**Table A- 1** and **Figure A-1**).

Table A-1. Predicted shade loss associated with different "shddenadd" factors for CIGF stands.

"shddenadd" Factor	Average shade loss associated 50ft Residual Buffer [19]	Average shade loss associated 75ft Residual Buffer
0.9	17.0	5.9
0.8	17.0	6.2
0.7	16.6	6.4
0.6	16.0	6.5
0.5	15.1	6.4
0.4	13.8	6.1
0.3	12.2	5.4
0.2	10.4	4.5
0.1	8.4	3.5

[18] Within the model the accumulated density of the non-overlapping and overlapping section of the shadow is not allowed to exceed 1.
[19] Average of 10ft, 20ft, and 30ft stream channels, averaged for the four CIGF forest groups listed in Table 3.

Figure A-1. Observed shade loss in field studies and modeled shade loss[20]
[Purple triangles represent model results associated with scenarios A-1 and B-1 in Table 1]



It is important to note that only one modeling node was utilized previously by USEPA during past modeling activities on this project (i.e., reported in the 4/2012 USEPA letter to the IFPA shade sub-committee), and thus the "shddenadd" factor was not utilized during these past modeling activities.

[20] "Residual "No-Cut" Buffer Width" refers to the un-cut riparian forest zone located between the stream and the outer clearcut harvest zone.

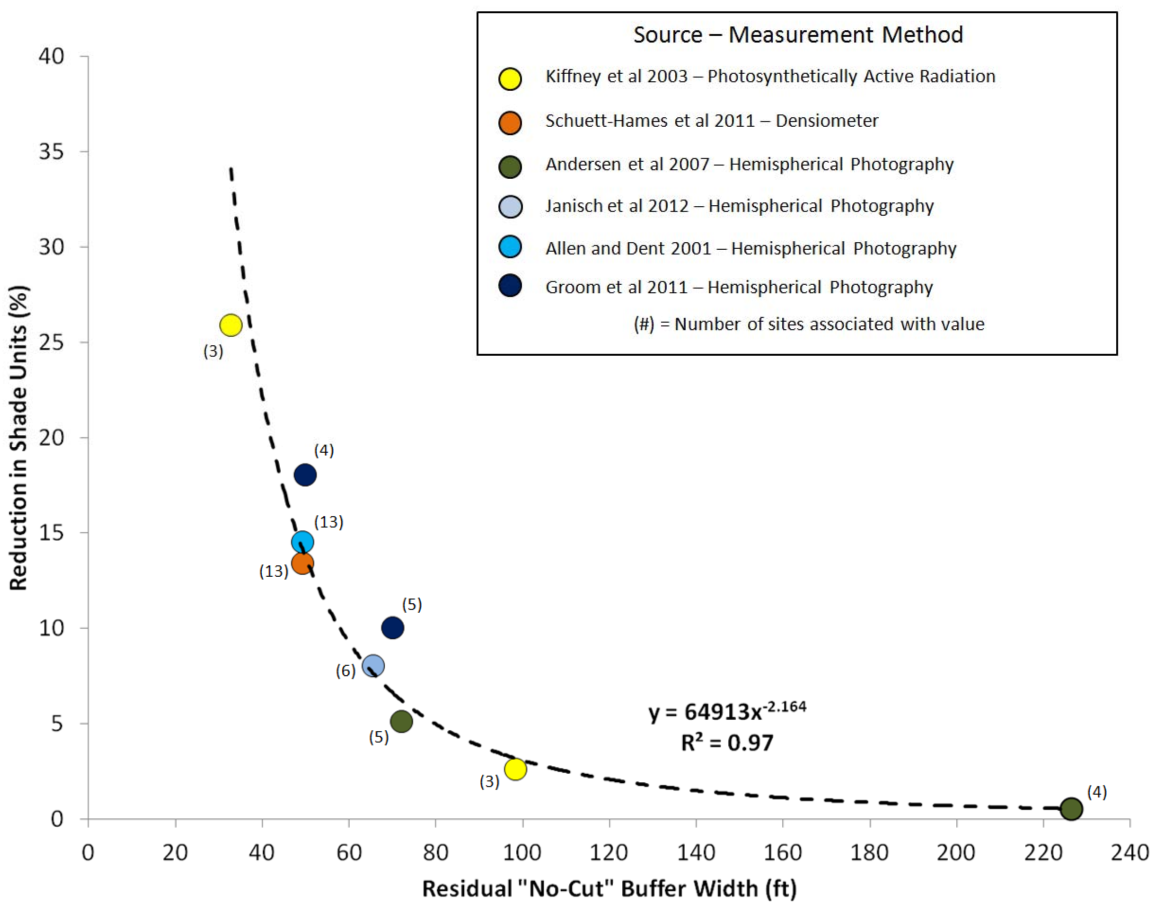
Appendix B – Field Studies

Annotated Bibliography - Literature Describing the Effects of Riparian Management on Stream Shade

This annotated bibliography includes original studies conducted on forestlands in the Pacific Northwest that used a BACI (Before-After/Control-Impact) design to investigate the effects of riparian buffers on stream shade and temperature conditions. Specifically, studies that included monitoring of both before and after treatment, and studies with untreated control sites were included in this review. In addition, only studies with a defined riparian no harvest buffer were included in this Appendix.

Figure B-1 illustrates reported shade loss in these studies resulting from a narrowing of the riparian buffer width. The x-axis shows the "no-cut" buffer width left next to the stream following clear-cut harvest activities. The y-axis is the reported average shade loss associated with the narrowing of the riparian buffer width. Also included in this figure is a trend line for this data ($r^2 = 0.97$).

Figure B-1. Measured shade loss associated with various "no-cut" riparian buffer widths.



Allen M., and L. Dent. 2001. Shade Conditions Over Forested Streams In the Blue Mountain and Coast Range Georegions of Oregon – ODF Technical Report #13.

Location: Coast Range of Oregon (45^o Latitude)

Synopsis: The Oregon Department of Forestry implemented a shade monitoring project in basins within the north coast and northeastern regions of Oregon (ODF Blue Mountain and Coast Range georegions). Discussions in this document will focus on sites associated with the Coast Range georegion. Data were collected on both harvested stream reaches and those with no recent history of harvest. One goal of this project was to determine the range of shade levels provided over streams under varying forest management scenarios. A second goal was to investigate possible links between site and stand characteristics and shade. The authors stated that the results from the Coast Range georegion are most appropriately applied to sites managed with a no-cut buffer.

Riparian Stand and Harvest Conditions:

Sites**:** 30 sites in the Coast Range of Oregon, of which 16 sites were managed with a "no-cut" buffer (however only 13 of these sites had both shade and buffer width data collect at them).

Stand Conditions: Riparian areas are typically dominated by an alder overstory and a salmonberry/sword fern understory. Riparian conifer species typically include western hemlock, western redcedar, and/or Sitka spruce. Douglas-fir is more prevalent farther away from the stream. Pre-harvest stand ages averaged 65 years.

Stream Conditions: The average stream width was 6.6 feet, and ranged from 3.2 to 12.8 feet.

Harvest conditions: The 13 sites in the Coast Range managed with a "no-cut" buffer had an average "no-cut" buffer width of 49.3 feet (15 m). Clearcut harvest occurred outside of this no-cut zone. Unharvested stand data were collected at sites adjacent, or in close proximity, to harvested stands in order to sample shade conditions that may have existed prior to entry. In order to collect data on a wide range of unharvested stands, this sample includes both young, intensively managed areas, as well as older stands.

Stream Length Logged: The plot had a minimum length of 500 feet and maximum length of 1000 feet.
Time line: Not described

Summary of Results:

Stream Shade Response - Thirteen of 16 no-cut sites in the Coast Range georegion had both shade measurements (collected by hemispherical photography at 3 feet over the stream surface) and the buffer width measurements. Buffer width was defined as the distance from the highwater mark to the first cut tree measured every 200 feet along the sample reach. The black circles on Figure 11 in the ODF report (shown below) depict these 13 no-cut sites for the Coast Range.

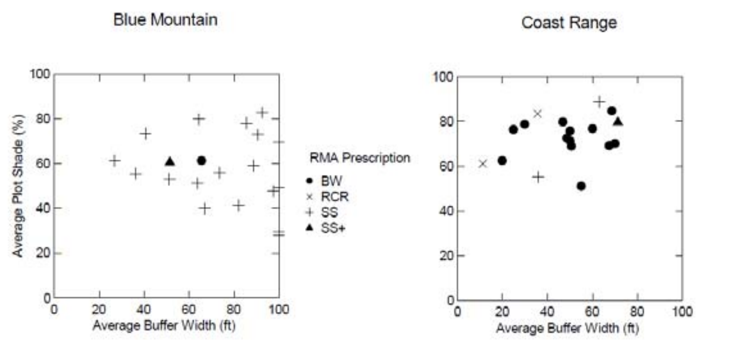
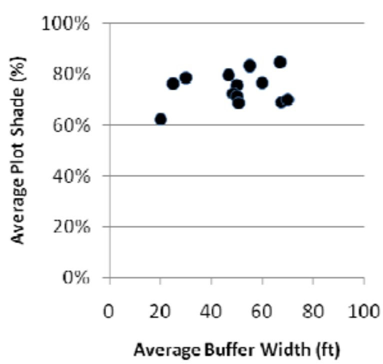


Figure 11. Average Plot Shade by average buffer width and RMA prescription for each georegion. SS = Site-Specific Prescription, SS+ = average buffer widths contain values that exceed 100 feet, BW = No-Cut Buffer, RCR = Riparian Conifer Restoration. Note: Only 38 sites had buffer width data.

Information for these 13 sites was obtained from Appendix A and B in this ODF technical report, along with the Microsoft Access database associated with this project (USEPA partially funded this project and the project database was a project deliverable). The image below illustrates this information for the 13 no-cut Coast Range sites. There is a difference in shade conditions at one of the sites presented below – The Microsoft Access database verified all of the information within Appendix A and B of this ODF technical report, except for this one shade measurement.



These 13 sites were located along small (11 sites) and medium (2 sites) stream size classes. The average stream width for these sites was 6.6 feet, and ranged from 3.2 to 12.8 feet. There were five small and medium sized unharvested streams in the Coast Range. The average shade measured at these unharvested sites was 89 % (i.e., 95, 85, 89, 93, and 83). The average difference in shade conditions associated with these 13 no-cut streams in the Oregon Coast Range was 14.5 units of shade, ranging from 4 to 27 units. The response would have been 16 units of shade reduction without the shade measurement correction described above.

<u>Stream Temperature Response -</u> Not measured

Anderson P. D., D. J. Larson, and S.S Chan. 2007. Riparian Buffer and Density Management Influences on Microclimate of Young Headwater Forests of Western Oregon ***Forest Science*** 53(2):254-269.

Location: Western Oregon

Abstract: Thinning of 30- to 70-year-old Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) stands is a common silvicultural activity on federal forest lands of the Pacific Northwest, United States. Empirical relationships among riparian functions, silvicultural treatments, and different riparian buffer widths are not well documented for small headwater streams. We investigated buffer width and density management effects on riparian microclimates of headwater streams in western Oregon. Spatial variations in stand density, canopy cover, and microclimate were measured along transects extending from stream center upslope into thinned stands, patch openings, or unthinned stands, with riparian buffers ranging from <5 m up to 150 m width. For treated stands, summer mean daily air and soil temperature maxima increased, and mean daily humidity minima decreased with distance from stream. Microclimate gradients were strongest within 10 m of stream center, a distinct area of stream influence within broader riparian areas. Thinning resulted in subtle changes in microclimate as mean air temperature maxima were 1 to 4°C higher than in unthinned stands. With buffers 15 m or greater width, daily maximum air temperature above stream center was less than 1°C greater, and daily minimum relative humidity was less than 5% lower than for unthinned stands. In contrast, air temperatures were significantly warmer within patch openings (+6 to +9°C), and within buffers adjacent to patch openings (+3°C) than within unthinned stands. Buffers of widths defined by the transition from riparian to upland vegetation or topographic slope breaks appear sufficient to mitigate the impacts of upslope thinning on the microclimate above headwater streams.

Riparian Stand and Harvest Conditions:

Sites**:** Five sites – Four along the Oregon Coast Range, and one site in the western edge of the Cascade Range in Oregon. In total, data from 40 transects distributed among 26 reaches across five sites were used in the analysis.

Stand Conditions: All sites were within the western hemlock vegetation zone and Douglas-fir dominated the 45- to 65 year old forests. Other vegetation in the stands included western hemlock and western red cedar. Basal area in unthinned stands ranged from about 44 to 58 m^2/ha.

Stream Conditions: First and 2nd order streams and active channel ranged from 0.2 to 3.7 m (averaged 1.1 m). Nearly 70% of the streams were summer intermittent.

Harvest conditions: There were two no-cut buffer treatments with clearcut harvest occurring outside of this inner zone: 1) “B1-P”– The no-cut buffer width average 69m; and 2) “VB-P” - The no-cut buffer width average 22m wide. There were several no-cut buffer treatments with thinning activities occurring outside of this inner zone: 1) “B1-T” (average 69m inner zone no-cut width); 2) “VB-T” (average 22m inner zone no-cut width); and “SR-T” (average 9m inner zone no-cut width). Thinning was to a density of 198 tree per hectare (tph). Unharvested controls reaches had around 500 to 750 tph (Chan et al., 2004). Unharvested control treatments were also included in the study (“UT”).

Stream Length Logged: Variable – results summarized from 40 transects and results for each transect was a discrete value (i.e., there was no cumulative effect).
Time line: None presented

Summary of Results:

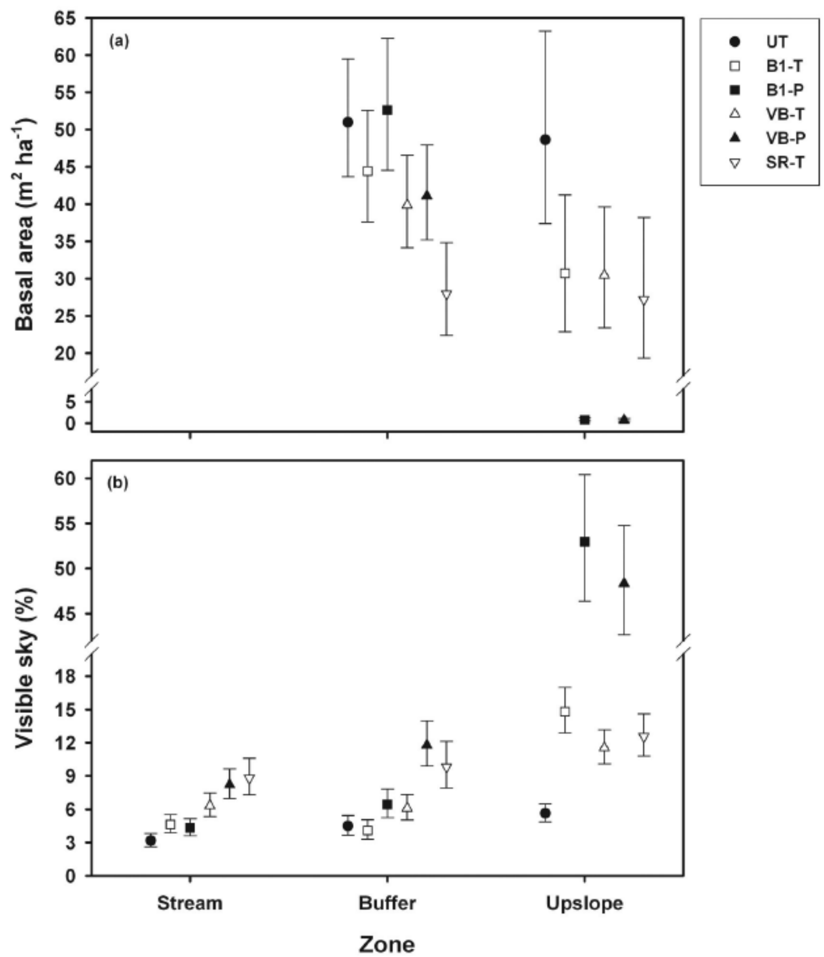


Figure 3. Treatment least-squares means (±1 standard error) for (a) basal area and (b) percentage visible sky as measured over stream center, within buffers, and within the upslope stands. Means and confidence intervals for *n* = four to five observations. Values are back-transformed from model estimates based on log-transformed data.

Stream Shade Response - Clearcut harvest outside of the 69m no-touch buffer ("B1-P") did not result in a significantly different light condition over the stream than the unharvested condition ("UT") and appears to be decreasing less than 1 unit of percent visible sky.

Clearcut harvest outside of the 22m no-touch buffer ("VB-P") resulted in significantly higher light conditions over the stream (p = 0.002), increasing 5.1 units of percent visible sky.

Stream Temperature Response - Not measured

Janisch J.E., S.M. Wondzell, and W.J. Ehinger. 2012. Headwater stream temperature: Interpreting response after logging, with and without riparian buffers, Washington, USA. *Forest Ecology and Management* doi:10.1016/j.foreco.2011.12.035.

Location: Western Washington (46.5^{o} Latitude)

Abstract: We examined stream temperature response to forest harvest in small (<9 ha) forested headwater catchments in western Washington, USA over a seven year period (2002–2008). These streams have very low discharge in late summer (mean≈ 0.3 L s^{-1}) and many become spatially intermittent. We used a before–after, control-impacted (BACI) study design to contrast the effect of clearcut logging with two riparian buffer designs, a continuous buffer and a patch buffer. We focused on maximum daily temperature throughout July and August, expecting to see large temperature increases in the clearcut streams (n = 5), much smaller increases in the continuously buffered streams (n = 6), with the patch-buffered streams (n = 5) intermediate. Statistical analyses indicated that all treatments resulted in significant (α= 0.05) increases in stream temperature. In the first year after logging, daily maximum temperatures during July and August increased in clearcut catchments by an average of 1.5 ^{o}C (range 0.2–3.6 ^{o}C), in patch-buffered catchments by 0.6 C (range 0.1–1.2 ^{o}C), and in continuously-buffered catchments by 1.1 ^{o}C (range 0.0–2.8 ^{o}C). Temperature responses were highly variable within treatments and, contrary to our expectations, stream temperature increases were small and did not follow expected trends among the treatment types. We conducted further analyses in an attempt to identify variables controlling the magnitude of post-harvest treatment responses. These analyses showed that the amount of canopy cover retained in the riparian buffer was not a strong explanatory variable. Instead, spatially intermittent streams with short surface-flowing extent above the monitoring station and usually characterized by coarse-textured streambed sediment tended to be thermally unresponsive. In contrast, streams with longer surface-flowing extent above the monitoring station and streams with substantial stream-adjacent wetlands, both of which were usually characterized by fine-textured streambed sediment, were thermally responsive. Overall, the area of surface water exposed to the ambient environment seemed to best explain our aggregate results. Results from our study suggest that very small headwater streams may be fundamentally different than many larger streams because factors other than shade from the overstory tree canopy can have sufficient influence on stream energy budgets to strongly moderate stream temperatures even following complete removal of the overstory canopy.

Riparian Stand and Harvest Conditions:

Sites**:** Five streams with clearcut harvest, six streams with continuously buffer streams, and five stream with patch-buffered streams.

Stand Conditions: Even aged stands ranging from 50 to 100 years, dominated by Douglas-fir and western hemlock. Conifers in all catchments were approximately 40 m tall. The forest canopy was closed, and was "providing dense shade throughout the catchment before logging". Red alder was the dominant hardwood species, and was more common in riparian areas.

Stream Conditions: Headwater streams draining small watersheds (average of 4.9 hectare size for continuous buffered streams). Mean BFW for the continuous buffered streams was 0.6 m, and the flow rate was around 0.01 cfs (i.e., 0.3 Ls^{-1}) in the late summer. The valley floor associated with these sites was generally only a few meters wide and often the bankfull stream channel occupied the fully width of the valley floor.

Harvest conditions: In small forested watershed (< 9 ha) the following three treatments were applied: (1) clearcut (n=5); (2) continuous buffered (n= 6); and (3) patch-buffered streams (n=5). In all three treatments, the upland portions of the catchments were clearcut harvested so that these treatments differed only in the way the riparian zone was harvested. The continuous riparian buffers reported in this study range from 10 to 15 meters on each side of the stream. Correspondences with the lead author of this study clarified the following widths of the continuous "no-touch" buffer: The no-touch buffer widths were variable, but on average the continuously buffered streams were around 20 meters on each side of the stream (estimated by the lead author through the use of aerial imagery). For patch buffers, portions of the riparian forest approximately 50-110 m long were retained in distinct patches along some portions of the headwater stream channel, with the remaining riparian area clearcut harvest. There was substantial variation in the locations of the patch treatments. For clearcut treatments, overstory trees were harvested from the catchment, including the entire riparian zone.

Stream Length Logged: The mean stream length of continuous buffered treatment streams was 279 meters, however only 43% of the stream length (on average) was observed to be flowing in the first post harvest year.

Time line: A seven year monitoring period (2002-2008), with three years of post harvest temperature data collection activities.

Summary of Results:

Stream Shade Response – Stream shade was calculated from hemispherical photography, and included both canopy and topography. Shade averaged 94% over the stream channel before logging and measured shade did not differ significantly between reference and treatment reaches. Stream shade in reference sites did not change substantially (average = 94%) after logging activities. Stream shade decrease on average to 86% for the continuous buffer treatment reaches. This corresponds to an average reduction of 8 units of stream "shade" associated with this treatment.

Stream Temperature Response – The temperature statistic used in this analysis was maximum daily temperature averaged over July and August. For continuous buffered catchments, temperature changes were significantly greater than zero (α = 0.05) in the first two post-treatment years. In the third post-treatment year, the magnitude of the temperature change estimated from the statistical model was significantly different for most of the monitoring period but not significantly different from zero after Julian day 228 (≈15th August). However, the absolute temperature response is still greater than zero during the last two weeks of the monitoring period. The July –August average temperature change for the three post-treatment years for the continuous buffered streams was 0.8 ^{o}C (i.e., (1.06+0.89+0.38)/3 = 0.8 ^{o}C). Temperature response was highest at the start of the evaluation period (i.e., July) and decreased in latter parts of the summer (i.e., July 1st average temperature response was approximately 1.3 ^{o}C, 1.1 ^{o}C and 0.8 ^{o}C in post-treatment year one, two and three, respectively). Accordingly, the estimated average July 1st temperature change for the three post-treatment years was 1.1 ^{o}C.

Table 2
Mean response of each treatment group in each post-logging year. A debris flow removed all riparian understory vegetation from one patch-buffered catchment between Years 2 and 3, leading to large temperature increases, so we also present treatment group means for patch-buffered catchments with that outlier removed from the calculation of temperature response in all three post-treatment years.

Treatment	Temperature response (°C)		
	Year 1	Year 2	Year 3
Continuous buffer	1.06	0.89	0.38
Patch buffer	0.61	0.67	0.91
Clearcut harvest	1.53	1.10	0.84
Patch buffer with outlier removed	0.73	0.72	0.16

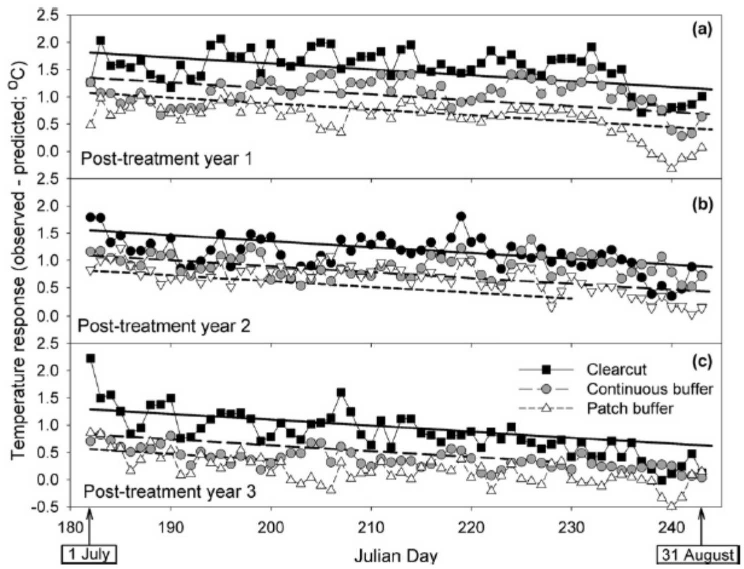


Fig. 4. Fit of the repeated-measures statistical model to the observed changes in stream temperature. Points represent the change in maximum stream temperature for each day of July and August, averaged over all catchments within a treatment group. The bold lines are the temperatures predicted from the statistical model where treatment, years post-treatment, and day of year were all fixed effects. These lines are only drawn for the dates over which the statistical model indicated a significant effect (i.e., stream temperatures were significantly different from 0.0 °C, $\alpha = 0.05$). Sample sizes per year for the clearcut, continuous, and patch treatments, respectively, were (A) Year 1: 5, 6, 5; (B) Year 2: 5, 6, 5; (C) Year 3: 3, 5, 5.

The observed variability of temperature response among catchments of the continuous buffer catchments, ranged from 0 to 2.8 °C in the first year after logging. Wetted stream length was shown to be a significant factor influencing the temperature response associated with riparian treatments, with greater responses associated with longer wetted stream lengths. In addition, the type of substrate was also shown to be a significant factor influencing temperature response, with a low response associated with coarse-substrate channels, and a large response associated streams with fine-texture streambed sediments. Shorter stream segment lengths were associated with coarse-substrate channels. The authors concluded that overall, the area of surface water exposed to the ambient environment best explained aggregated temperature response.

Temperature response successively decreased in the three years following the treatment; however there was still a significant response in temperature at post-harvest year 3.

Variable Buffer Widths and Water Quality – Malcolm Knapp Research Forest Study

Kiffney, P. M., J. S. Richardson, J. P. Bull. 2003. Responses of periphyton and insect consumers to experimental manipulation of riparian buffer width along headwater streams. *Journal of the American Water Resources Association* 40:1060-1076.

Location: Coastal British Columbia (49^{o} Latitude)

Abstract: Riparian trees regulate aquatic ecosystem processes, such as inputs of light, organic matter and nutrients, that can be altered dramatically when these trees are harvested. Riparian buffers (uncut strips of vegetation) are widely used to mitigate the impact of clear-cut logging on aquatic ecosystems but there have been few experimental assessments of their effectiveness. Forests along 13 headwater stream reaches in south-western British Columbia, Canada, were clear-cut in 1998, creating three riparian buffer treatments (30-m buffer, 10-m buffer and clear-cut to the stream edge), or left as uncut controls, each treatment having three or four replicates. We predicted that periphyton biomass and insect consumers would increase as buffer width decreased, because of increased solar flux. We used two complementary studies to test this prediction. In one study, we compared benthic communities before and after logging in all 13 streams; a second study focused on periphyton and insect colonization dynamics over 6-week periods in each of four seasons in four streams, one in each treatment. Photosynthetically active radiation, and mean and maximum water temperature, increased as buffer width narrowed. Periphyton biomass, periphyton inorganic mass and Chironomidae abundance also increased as buffer width narrowed, with the largest differences occurring in the clear-cut and 10-m buffer treatments. Photosynthetically active radiation, water temperature, periphyton biomass and periphyton inorganic mass were significantly greater in the 30-m buffer treatment than in controls during some seasons. We have shown that a gradient of riparian buffer widths created a gradient in light and temperature that led to non-linear increases in periphyton biomass and insect abundance. For example, Chironomidae abundance was generally greater in the 10-m and 30-m buffer treatments than in controls, whereas this was not always the case in the clear-cut treatment. This pattern may be due to the high sediment content of the periphyton mat in the clear-cut treatment, which potentially limited the response of some insects to increased food resources. Overall, our results indicate that uncut riparian buffers of 30-m or more on both sides of the stream were needed to limit biotic and abiotic changes associated with clear-cut logging in headwater, forested watersheds.

Riparian Stand and Harvest Conditions:

Sites: 13 headwater streams in South-Western British Columbia, Canada.

Stand Conditions: 550-650 trees/ha, average dbh 40 cm, average height 45 m, average age 70 years, and western hemlock, western red cedar, and Douglas-fir were the dominate species.

Stream Conditions: headwater streams

Harvest conditions: Riparian no-touch buffer widths of 10m and 30m, zero m, and control (unharvested).

Stream Length Logged: Ranged from 215 to 650 meters

Time line: Pre-harvest data and one year of post-harvest data collection.

Summary of Results:

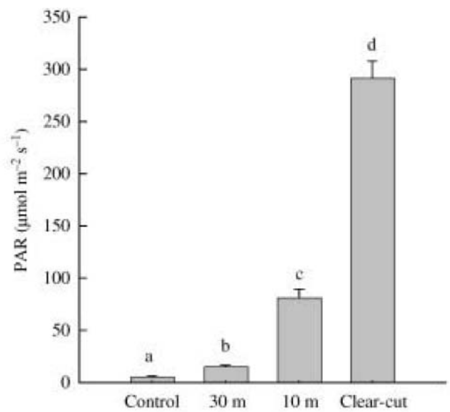


Fig. 2. Mean (1 SD) annual PAR (400–700 nm) measured in each treatment the first year after logging. Means with the same letter were not statistically different based on the within-season comparison.

Mean solar flux (Photosynthetically active radiation – PAR) reaching streams with clear-cut (zero meters), 10-m, and 30-m buffers was 58, 16, and 5 times greater, respectively compared to the control sites. This corresponds with an approximate reduction of 2.6 and 25.9 units of shade associated with the 30 m and 10 m buffers, respectively, as compared to the control. Authors concluded that "our observations suggest that additional light penetration comes through the sides of the buffer" and that there was a significant relationship between light levels and buffer width along small streams. Compared with controls, mean daily maximum summer water temperatures increased by 1.6, 3.0, and 4.8 degrees Celsius for the 30 m, 10 m and zero meter (clearcut) harvest treatments, respectively.

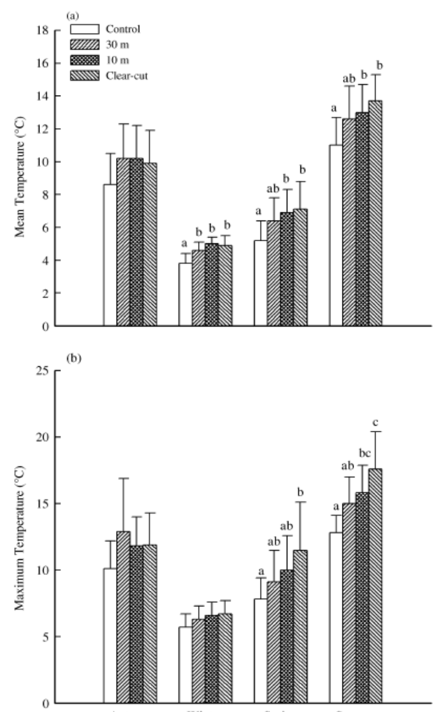


Fig. 3. Mean (1 SD) (a) daily and (b) maximum daily water temperature in each riparian treatment in each season the first year after logging. Means with the same letter were not statistically different based on the within-season comparison.

Variable Buffer Widths and Water Quality – Westside Type N Buffer Study – CEMR

Schuett-Hames., D., A. Roorbach, and R. Conrad. 2011. Results of the Westside Type N Buffer Characteristics, Integrity and Function Study – CEMR Final Report. December 14, 2011

Location: Western Washington

Executive Summary Conclusions: This study provides insights into the harvest unit-scale effects of the westside Type Np riparian prescriptions on riparian stand condition, and riparian processes and functions including tree fall, wood recruitment, channel debris, shade, and soil disturbance. The nature and magnitude of responses varied, depending on whether the reaches were clear-cut or buffered, and in the case of the buffered reaches, on the magnitude of post-harvest disturbance from wind-throw. The study evaluated prescription effectiveness by comparing the treatments with unharvested reference sites of similar age. Since many of the FFR resource objectives for Type Np streams are intended to protect amphibians and downstream fish and water quality, the results of this study do not provide a complete story of prescription effectiveness. Combining the results of this study with sub-basin scale studies that examine the effects of the prescription on aquatic organisms and exports of heat, sediment and nutrients to fish-bearing streams will provide a more complete assessment of prescription effectiveness.

Riparian Stand and Harvest Conditions:

Sites: 24 non-fish bearing headwater streams in the western hemlock zone of western Washington

Stand Conditions: Randomly selected sites to provide an unbiased estimate of variability associated with the prescriptions when applied in an operational timber harvest setting under a range of site conditions across western Washington. Mean common tree height was 95 feet, and ranged from 60 to 128 feet. The mean site index was 122.

Stream Conditions: Mean bankfull width was 6 feet, and ranged from 3.1 to 11.4 feet.

Harvest conditions: Eight sites had clear-cut harvest to the edge of the stream (clear-cut patches), thirteen had 50 foot wide no-cut buffers on both sides of the stream (50-ft buffers), and three had circular no-cut buffers with a 56 foot radius around the perennial initiation point (PIP buffers). An un-harvested reference reach was located in close proximity to each treatment site (not within 100 feet of the treatment site).

Stream Length Logged: Both sides of a Type Np stream had to be harvested under the westside Type Np riparian buffer prescriptions for at least 300 ft (except for circular perennial initiation point buffers) without a stream adjacent road.

Time line: Data were collected one year after harvest (2004), again in 2006 (three years after harvest), and in 2008 (five years after harvest).

Summary of Results:

The first year following harvest stream shade decreased 13.4% units for the 13 sites with a 50-ft buffer.

In the years following harvest, tree mortality rates exceeded 50% at three of the 50-ft buffer sites. Mean tree mortality was 68.3% for these buffers over the five year period, and exceeded 90% in one case. The mean density of the remaining live trees was 62.8 trees/acre. The channels received a large pulse of

LWD input from wind-thrown trees, however most wood was suspended over or spanning the channel and mortality has reduced the supply of trees available to provide future LWD. Mean overhead shade five years after harvest was about 30% lower than the reference reaches; however cover from understory plants and channel debris increased. Soil disturbance from uprooted trees in the first five years after harvest was over five times the rate for the reference reaches, but most root-pits did not deliver sediment.

The majority of 50-ft buffers (10 of 13) had tree mortality rates less than 33% over the five year post-harvest period. Mean tree mortality for these buffers was 15%, and the mean density of live trees was 140 trees/acre five years after harvest (range 59-247). Overhead shade in this group of buffers was reported 10-13% less than the reference reaches. These buffers had minimal soil disturbance from uprooted trees in the first five years after harvest.

Shade

Table 49. Descriptive statistics for stream shade metrics by patch type; one year (2004), three years (2006) and five years (2008) after harvest.

Patch Type	n	Overhead Cover (viewed from stream)		Percentage of Channel Obscured by Understory Plant Cover	
		Mean	SD[1]	Mean	SD[1]
2004					
Reference	14	89.3 %	4.4 %	14.3 %	8.3 %
50-ft buffer	13	75.9 %	15.7 %	28.9 %	16.8 %
Clear-cut	8	12.0 %	12.7 %	17.8 %	13.1 %
PIP buffer	3	54.9 %	21.2 %	37.3 %	26.4 %
2006					
Reference	13	93.3 %	4.9 %	13.3 %	4.7 %
50-ft buffer	12	80.8 %	19.9 %	31.3 %	20.2 %
Clear-cut	7	14.0 %	14.4 %	38.7 %	31.1 %
PIP buffer	3	65.0 %	13.2 %	29.4 %	14.6 %
2008					
Reference	14	90.2 %	4.6 %	16.0 %	16.8 %
50-ft buffer	13	80.6 %	15.7 %	34.7 %	21.0 %
Clear-cut	8	36.5 %	27.6 %	41.2 %	24.4 %
PIP buffer	3	61.7 %	21.4 %	47.4 %	38.1 %

[1] SD = standard deviation

Variable Buffer Widths and Water Quality – Ripstream Project

Groom J. D., L. Dent, L. Madsen, J. Fleuret. 2011. Response of western Oregon (USA) stream temperatures to contemporary forest management. *Forest Ecology and Management* 262(8):1618–1629.

Location: Western Oregon coast range (45^{o} Latitude)

Abstract: A replicated before–after-control-impact study was used to test effectiveness of Oregon's (USA) riparian protection measures at minimizing increases in summer stream temperature associated with timber harvest. Sites were located on private and state forest land. Practices on private forests require riparian management areas around fish-bearing streams; state forest's prescriptions are similar but wider. Overall we found no change in maximum temperatures for state forest streams while private sites increased pre-harvest to post-harvest on average by 0.7 °C with an observed range of response from −0.9 to 2.5 °C. The observed increases are less than changes observed with historic management practices. The observed changes in stream temperature were most strongly correlated with shade levels measured before and after harvest. Treatment reach length, stream gradient, and changes in the upstream reach stream temperature were additionally useful in explaining treatment reach temperature change. Our models indicated that maximum, mean, minimum, and diel fluctuations in summer stream temperature increased with a reduction in shade, longer treatment reaches, and low gradient. Shade was best predicted by riparian basal area and tree height. Findings suggest that riparian protection measures that maintain higher shade such as the state forests were more likely to maintain stream temperatures similar to control conditions.

Riparian Stand and Harvest Conditions:

Sites: Thirty three (33) first and third order streams on 18 private sites and on 15 State forest sites. It is important to note that only sites listed as either having a "No-Touch" or "No-Entry" zone along the entire treatment length on both stream banks were included in the development of average shade loss response for this study, as presented in **Figures 2, A-1, and B-1**.

Stand Conditions: Dominated by Douglas fir and red alder. Forest stands were 50-70 years old and were fire- or harvest regenerated. Mean measured tree height was 25.7 m. Sites with evidence of debris torrent or beaver disturbance were excluded. Pre-treatment buffer basal area (m^2/ha) was 41 and 43 for state and private sites, respectively.

Stream Conditions: First and third order streams. Average BFW was 4.6 and 4.1 meters for state and private sites, respectively. Average wetted width was 2.3 and 2.0 meters for state and private sites, respectively.

Harvest conditions: There was an upstream control reach for each sample reach (average length of 684 m). There was also a downstream "recovery" reach for many of these sites. Average "no touch" buffer width for the private sites was 26 m (85 ft), and ranged from 14 to 36 m (The reported mean distance was 31m and was defined as "the perpendicular distance from the stream bank to the first stump encountered within 10 m of the observer, measured every 60 m along the treatment reach." It was assumed that, on average, that the perpendicular distance of the stump to the stream will be 5 meters further from the stream than the observer (i.e., 31 m – 5 m = 26 m).). Using a similar calculation, the average “no touch” buffer width for the state sites was 46.8 m (154 ft), and ranged from 20 to 56 m. Thirteen (13) of the 15 State sites had harvest on only one bank of the river, and 4 of the 18 private sites had harvest on only one bank of the river.

Stream Length Logged: Average treatment length was 800 and 600 meters for state and private sites, respectively. Minimum treatment length target was 300m.

Time line: 2002 through 2008 - Two years of preharvest data and five years of post harvest data. Temperature analysis was limited to all of the pre-harvest data (two years for most sites and more at others) and two years of post-harvest data.

Summary of Results:

Table 5
Mean and range values for State and Private independent variables and site characteristics. Values are calculated from 15 State sites and 18 Private sites. Pre and Post refer to measurements taken preharvest or postharvest. For Shade ranges see Fig. 4; basal area and trees per hectare are BAPH and TPH, respectively.

Variable	State		Private	
	Mean	Range	Mean	Range
Gradient (%)	6.5	1.5–13.2	6.4	1.0–17.5
treatment Length (km)	0.8	0.3–1.5	0.6	0.3–1.8
Elevation (m)	350	160–570	300	3–900
Watershed area (ha)	222	72–593	208	27–626
Crown ratio	0.43	0.30–0.56	0.40	0.26–0.57
Buffer width (m)[a]	51.8	25–61	31	19–41
Bankfull width (m)	4.6	2.7–7.9	4.1	2.2–7
Wetted width (m)	2.3	1.3–3.7	2.0	1.0–3.0
Thalweg (cm)	17	9–30	15	8–24
Basal area (m /ha)				
Pre-harvest	41	19–74	43	23–73
Post-harvest	42	25–73	25	11–40
Trees per ha				
TPH pre	368	147–665	465	196–664
TPH post	387	128–645	270	111–429
Tree height (m)	26	17–37	25	18–31

[a] Means reported in Groom et al. (2011); 95% CI for State sites = 45.6 m, 58.0 m; 95% CI for Private sites = 26.7 m, 35.3 m.

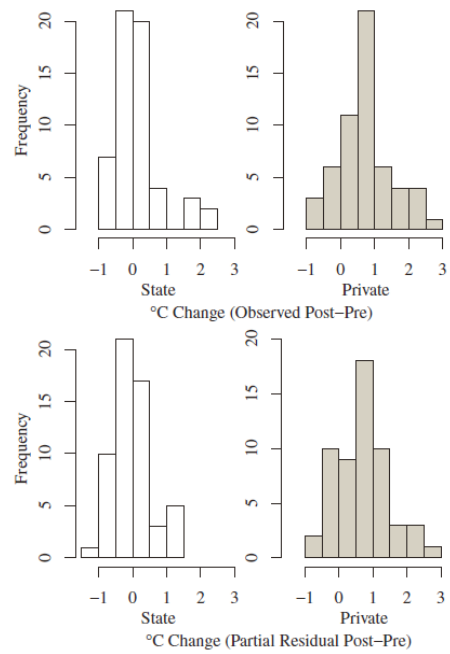


Fig. 6. Within-site pairwise differences in temperature change between post-harvest and pre-harvest values for Maximum observed data and partial residuals. Observed values are presented individually in Fig. 3. Partial-residual values represent observed values but control for site treatment reach length, upstream control temperature change, and stream gradient.

Vegetation Response - Average post-treatment buffer **basal area** (m^2/ha) for state sites was 42, which is an increase over pre-harvest levels (i.e., Pre-harvest levels were 41 m^2/ha). This result was most likely a result of two factors: 1) the “no-touch” buffer associated with state sites was 51.8 m, and 2) Only limited selective harvest occurred outside of this zone at many of these sites. Average private site post-harvest basal area were reduced by around half (i.e., Pre-harvest levels were 43 m^2/ha and post-harvest levels were 25 m^2/ha). Reductions at private sites may be occurring for two reasons: 1) The average “no-touch” buffer zone width was 26 m; and 2) Harvest activities outside of this zone were all “clearcut”. Thus, basal area reductions following harvest is primarily a result of vegetation removal in the outer zone of the riparian zone (The riparian area was defined in this study as a 170 ft (53 m) distance from the stream, which corresponds to the riparian management area (RMA)).

<u>Stream Shade Response -</u> Private site post-harvest **stream shade** values differed significantly from pre-harvest values (mean change in Shade from 85% to 78%); however, only a small difference was observed for state site stream shade values (mean change in Shade from 90% to 89%). The shade model BasalXHeight which included parameters for basal area per hectare (BAPH), tree height, and their interaction was best-supported: Its model weight (ω = 1.00) indicated strong relative support for this model and virtually no support for the remaining models. (BAPH and Height variables were calculated by using vegetation plot data from the edge of the bank to a perpendicular distance of 30 m, a distance at which they surmise that tree canopies have likely ceased to influence stream shade during daily periods of the greatest radiation intensity (mean measured tree height = 25.7 m).) Accordingly, stream shade conditions were shown to be a function of tree height and stand density (i.e., basal area - BAPH). Between 68% and 75% of variability in post-harvest shade may be accounted for by basal area within 30 m of the stream, tree height, and possibly blowdown. Sites with wider uncut buffers, or fewer stream banks harvested had greater basal area (i.e., BAPH). Sites with higher basal area within 30 m of the stream resulted in higher post-harvest shade.

<u>Stream Temperature Response -</u> The authors determined that maximum, Average, Minimum, and Diel Fluctuation **stream temperatures** increased as a consequence of timber harvest. Particularly, ranking models determined that by far the most critical driver for stream temperature change was shade. In addition, they generally observed an increase in maximum temperature pre-harvest to post-harvest for sites that exhibited an absolute change in shade of > 6%; otherwise, directionality appears to fluctuate.

A comparison of within-site changes in ***maximum temperatures*** from pre-harvest to post-harvest indicated an overall increase in Private site temperatures while observed changes at State sites were as frequently positive as negative: The average observed maximum change at State sites was 0.0 °C (range = −0.89 to 2.27 °C); and the average observed maximum temperature change at Private sites averaged 0.73 °C (range = −0.87 to 2.50 °C), and Private sites exhibited a greater frequency of post-harvest increases from 0.5 to 2.5 °C compared to State sites. They repeated this comparison while controlling for the effects of control reach temperature change, treatment reach length, and gradient by plotting differences in partial residuals from the Maximum temperature model Grad_Shade (each datum = model residuals + predicted effect of Shade). They found that State site differences became less extreme for positive increases (<1.5 °C) while private comparisons appeared to occupy the same range of responses. Using a linear mixed effects model ("HarvestPrivate") the authors determined that maximum temperatures at Private sites increased ***relative to State sites*** on average by 0.71 C, mean temperatures increased by 0.37 C, Minimum temperatures by 0.13 C, and Diel Fluctuation increased by 0.58 C.

The authors did not report on temperature recovery.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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March 14, 2013

Craig Foss
Bureau Chief
IDL Forestry Assistance Bureau
3284 W. Industrial Loop
Coeur d'Alene, Idaho 83815

RE: Idaho Shade Requirements for Forested Lands

Dear Mr. Foss:

The Environmental Protection Agency (EPA) has appreciated the opportunity to participate in development of the State's Shade Rule. We believe that the substantial, continued efforts of the Idaho Department of Lands (IDL) and the Forest Practices Act Advisory Committee (FPAAC) members to develop a strong scientific body of work that can be used to support development of Streamside Protection Zone (SPZ) options is both commendable and warranted. The State's Shade Rule is IDL's primary requirement on private forest lands for meeting Idaho water quality standards. Stream temperatures naturally exceed applicable criteria in many forested areas and, as noted below, Idaho water quality standards address this circumstance.

"When natural background conditions exceed any applicable water quality criteria set forth in Sections 210, 250,251,252, or 253, *the applicable water quality criteria shall not apply; instead, there shall be no lowering of water quality from natural background conditions" (IDAPA 58.01.02.200.09. Natural Background Conditions as Criteria).*

Given Idaho's water quality standards, the potential effects of riparian management on water quality and the body of science documenting the effects of shade loss on stream temperature increases, we strongly support development of SPZ management options with a high likelihood of preventing impacts to water quality and associated designated uses. To that end we have worked with IDL, FPAAC members, Tribal interests, and other scientists to help strengthen the technical modeling being used to support development of SPZ options. The attached document continues EPA's support for development of Idaho's Shade Rule efforts.

We recommend providing shade rule options for forest landowners that prevent lowering of shade levels, particularly where natural background conditions exceed applicable water quality criteria. We recognize that management requirements for SPZs can have significant economic and forest health implications. Five SPZ management scenarios in the attached analysis would limit shade loss to 10% or less while allowing harvest within all or a portion of the SPZ.

Thank you again for providing an opportunity for EPA to engage in shade rule development. If you have any questions, please contact David Powers at 503-326-5874 or powers.david@epa.gov.

Sincerely,

James Werntz, Director
Idaho Operations Office

Enclosure

cc: Michael McIntyre
Surface Water Program Manager
Idaho Department of Environmental Quality

Ara Andrea
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Idaho Department of Lands